057:20 **TEST # 3** **Fall 2004**

Prob. 1

Information and assumptions

Find

Is the magnitude of the shear stress greater at the moving plate or at the stationary plate?

Solution

Develop an equation for the shear stress

$$\tau = \mu \frac{du}{dy}$$ (Eqn. = 7)

$$= -\mu \left(\frac{1}{2\mu} \right) \left(\frac{dp}{ds} \right) (H - 2y) + \mu \frac{u_t}{H}$$

Evaluate τ at $y = H$:

$$\tau_H = \frac{1}{2} \left(\frac{dp}{ds} \right) H + \mu \frac{u_t}{H}$$

Evaluate τ at $y = 0$:

$$\tau_0 = -\frac{1}{2} \left(\frac{dp}{ds} \right) H + \mu \frac{u_t}{H}$$ (Inter. = 2)

Observation of the velocity gradient lets one conclude that the pressure gradient dp/ds is negative. Also u_t is negative. Therefore:

$$|\tau_H| > |\tau_0|$$ (Ans. = 1)

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Prob. 2

Information and assumptions

Provided in problem statement

Find

Force at flange to hold nozzle in place

Solution

Velocity calculation

$$v_1 = \frac{Q}{A_1} = \frac{15}{(\pi/4)\times 1^2} = 19.10\ ft/s$$

$$v_2 = \frac{Q}{A_2} = \frac{15}{(\pi/4)\times (8/12)^2} = 42.97\ ft/s$$

(Eqn. + Ans. = 2)

Bernoulli eqaution

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

(Eqn.= 2)

$$p_1 = 0 + \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$= 1,437\ lbf/ft^2$$

(Inter.+ Ans.= 1)

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x-momentum equation

$$\sum F_x = \dot{m}_2 v_2 - \dot{m}_1 v_1$$

(Eqn.= 4)

$$p_1 A_1 + F = (1.94\times 15)\times 42.97 - (1.94\times 15)\times 19.10$$

$$1,437\times\left(\frac{\pi}{4}\right)\times 1^2 + F = (1.94\times 15)\times(42.97 - 19.10)$$

$$F = -434 lbf\ (act\ \ to\ \ left)$$

(Inter. + Ans. = 1)

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Prob. 3

Information and assumptions

Provided in problem statement

From Table A.3 $\nu = 1.5\times10^{-5}\, m^2/s$ and $\rho = 1.2\, kg/m^3$

Find

Total drag force on plate

Solution

The force due to shear stress is

$$F_s = C_f \frac{1}{2}\rho U_0^2 BL$$

(Eqn. = 6)

The Reynolds number based on the plate length is

$$\mathrm{Re}_L = \frac{U_0 L}{\nu} = \frac{15\times1}{1.5\times10^{-5}} = 10^6$$

(Inter. + Ans. = 1)

The average shear stress coefficient on the tripped side of the plate is

$$C_f = \frac{0.074}{\left(10^6\right)^{1/5}} = 0.0047$$

(Inter. + Ans. = 2)

The totaol force is

$$F_x = 0.0047\times\left(\frac{1}{2}\times1.2\times15^2\right)\times\left(1.0\times0.5\right) = 0.317\,N$$

(Inter. + Ans. = 1)

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Prob. 4

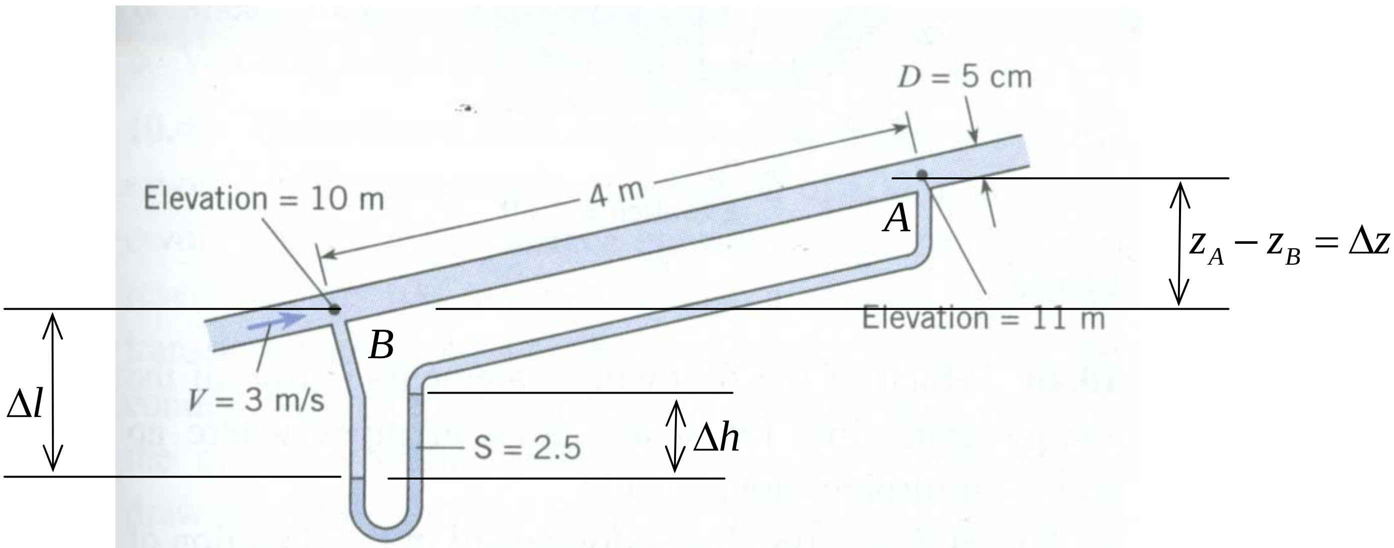
Information and assumptions

Provided in problem statement

Find

Resistance coefficient

Solution



Manometer equation

$$p_B + \gamma_f \Delta l - \gamma_m \Delta h - \gamma_f \left[(\Delta l - \Delta h) + \Delta z \right] = p_A$$

$$p_B - \gamma_m \Delta h - \gamma_f \left[-\Delta h + (z_A - z_B) \right] = p_A$$

$$p_B - (\gamma_m - \gamma_f) \Delta h - \gamma_f z_A + \gamma_f z_B = p_A$$

$$(p_B + \gamma_f z_B) - (p_A + \gamma_f z_A) = (\gamma_m - \gamma_f) \Delta h$$

$$p_{zB} - p_{zA} = (\gamma_m - \gamma_f) \Delta h$$

$$\Delta h = \frac{p_{zB} - p_{zA}}{\gamma_f} = \frac{(\gamma_m - \gamma_f) \Delta h}{\gamma_f} = \left(\frac{\gamma_m}{\gamma_f} - 1 \right) \Delta h = (2.5 - 1) \Delta h$$

$$\Delta h = h_f = 0.80 \times (2.5 - 1) = 1.2 m$$

(Eqn + Inter.+ Ans. = 3)

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

(Eqn = 6)

$$f = 1.2 \times \left(\frac{0.05}{4} \right) \times \frac{2 \times 9.81}{3^3} = 0.033$$

(Inter.+ Ans. = 1)

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Prob. 5

Information and assumptions

Provided in problem statement

From Table 10.3: $K_e = 0.03$; $K_b = 0.35$; $K_E = 1.0$

From Table A.5, $\nu = 10^{-6}\, m^2/s$

From Table 10.2, $k_s = 0.046mm$

Find

The pump power

Solution

Energy equation from the water surface in the lower reservior to the water surface in the upper reservior

$$p_1/\gamma + V_1^2/2g + z_1 + h_p = p_2/\gamma + V_2^2/2g + z_2 + \sum h_L$$

$$0 + 0 + 200m + h_p = 0 + 0 + 235m + \frac{V_2^2}{2g}\left(K_e + K_b + K_E + f\frac{L}{D}\right)$$

(Eqn = 7)

$$V = \frac{Q}{A} = \frac{0.314}{\left(\frac{\pi}{4}\right)\times 0.3^2} = 4.442\, m/s, \qquad \frac{V^2}{2g} = 1.01m$$

$$\text{Re} = \frac{VD}{\nu} = \frac{4.44\times 0.3}{10^{-6}} = 1.33\times 10^6, \qquad \frac{k_s}{\nu} \approx 0.00015$$

So from Figure 10.8 $f = 0.014$

$$f\frac{L}{D} = 0.014\times\frac{140}{0.3} = 6.53$$

(Inter.+ Ans. = 2)

$$h_p = 235 - 200 + 1.01\times(0.03 + 0.35 + 1 + 6.53) = 43.0m$$

$$p = Q\gamma h_p = 0.314\times 9,790\times 43.0 = 132kW$$

(Inter.+ Ans. = 1)

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Prob. 6

Information and assumptions

Provided in problem statement

From Table A.3, $\rho = 0.00237\, slugs/ft^3$; $\nu = 1.58\times10^{-4}\ ft^2/s$

Find

Drag on cooling tower

Solution

$$V = 4.31 mph = 6.32\ ft/s$$

$$\mathrm{Re} = \frac{V_0 d}{\nu} = \frac{6.32\times250}{1.58\times10^{-4}} = 1.0\times10^7$$

From Figure 11.5: $C_D = 0.70$ (Eqn. = 2)

Then

$$F_D = C_D A_p \frac{1}{2}\rho V^2$$ (Eqn. = 7)

$$= 0.70\times250\times350\times\frac{1}{2}\times0.00237\times6.32^2$$

$$= 2{,}899 lbf$$ (Inter.+ Ans. = 1)
